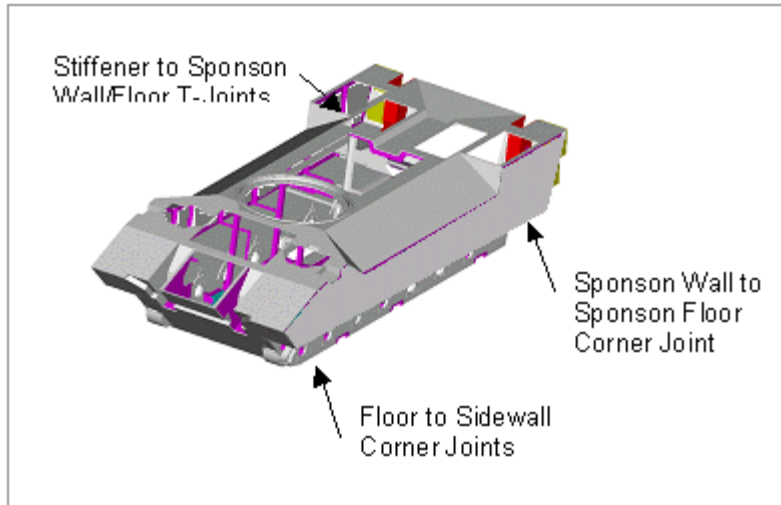
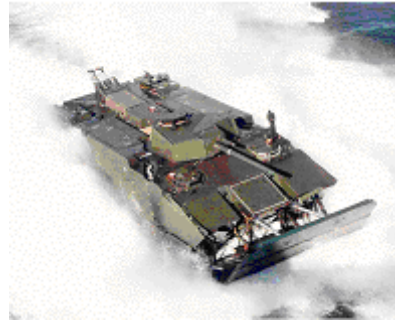


FRICTION STIR WELDING OF ALUMINUM ARMOR FOR THE AAV



PROBLEM / OBJECTIVE

The Marine Corps is developing a new Advanced Amphibious Assault Vehicle (AAAV) to be fabricated from high-strength aluminum armor. The vehicle structure consists of a welded frame design, which is made of aluminum alloy 2519-T87. One of the manufacturing challenges on this vehicle is development of productive and cost-effective methods of welding the vehicle structure while maximizing ballistic performance.

In 1998, General Dynamics Land Systems Inc. (GDLS) and Edison Welding Institute (EWI) demonstrated that friction stir welding (FSW)

offered a number of advantages for welding 2519 material. Test panels, which successfully passed ballistic tests, confirmed the ability of the solid state FSW process to produce welds that are stronger and more ductile than can be achieved with arc welding processes.

This Navy ManTech project was initiated to further refine the FSW process for specific AAAV applications and transition the technology onto the manufacturing floor. The objectives of this FSW project were to produce welds with greater strength and increased ductility compared to conventional arc welds and to reduce fabrication costs by reducing process cycle time and distortion.

APPROACH/BUSINESS STRATEGY

This NJC project focused on two major tasks; 1) development and transition of FSW tools and procedures for 0.5, 1.0 and 1.5-in. thick butt joints and 2-in. to 1-in. thick corner joints, and 2) development, validation, and transition of a distortion model, FSW procedures, and tools needed to produce low distortion corner and T-joints for fabrication of the sponson subassembly.

This project demonstrated that FSW has productivity, distortion, and ballistic performance advantages on the AAAV application compared to conventional gas metal arc welding (GMAW). Optimum welding procedures were developed, mechanical properties evaluated, and process control methods were developed to assure production quality is maintained. Final production welding procedures were demonstrated on ballistic test panels and prototype components, and the technology was transferred to General Dynamics Land Systems.

ACCOMPLISHMENTS/PAYOFF

Process Improvement

GDLS and EWI have developed highly productive FSW procedures to join 2519-T87 aluminum armor plate in butt, corner, and T-joint joint configurations over a range of material thickness combinations. FSW



mechanical properties were found to have improved strength and increased ductility compared to conventional arc weld properties. FSW became the first joining process to pass ballistic qualification on 2519 aluminum in a butt weld configuration.

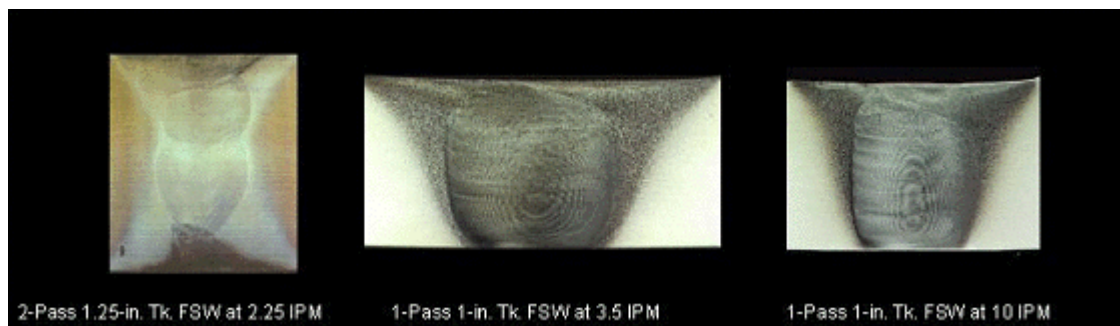
Ballistic Testing

The U.S. Army Aberdeen Test Center conducted a series of ballistic tests on the FSW plates at Aberdeen Proving Ground from early 1999 through 2002. The goal of the test is to measure the ability of the weld to resist cracking under ballistic shock load. Both butt and corner joints can be evaluated with the shock test.

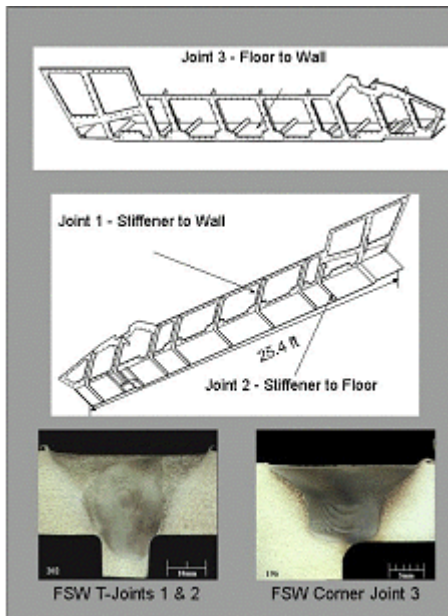
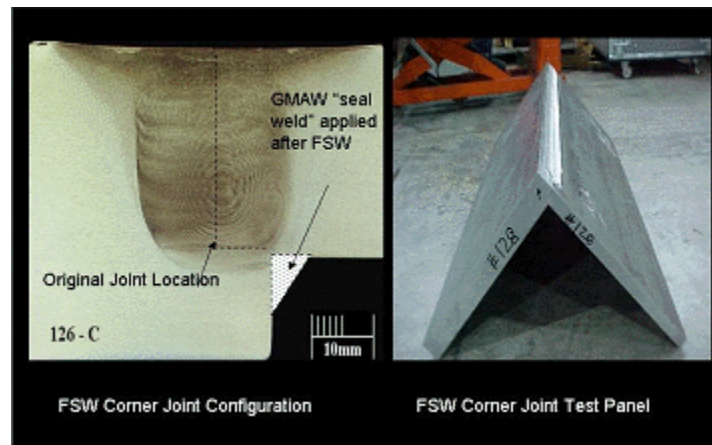
The initial 2-pass GDLS/EWI FSW on 1.25-in. thick 2519 plate was the first butt joint to pass the shock test. Since that time, high productivity single pass butt (1-in. thick) and corner (2-in. to 1-in.) joints have also been qualified. The corner joint test represented the first successful ballistic test for this configuration using the FSW process.

Productivity

GDLS and EWI built on the initial development work that used a 2-pass FSW procedure to weld thick plate. The range of material thickness being joined was expanded to include 0.5, 1.0, and 1.5-in. plate using a single pass approach. High productivity single-pass procedures were developed and tested for 2519 aluminum armor. The improved procedures enabled the productivity to be increased by over 400% for 1.0-in. thick plates compared to the original 2-pass procedure. Through further tool/process refinement, 1-in. thick FSW have been produced at travels speeds of up to 10 ipm. The welds made at higher travel speeds have the added benefit of less heat input into the joint, which reduces distortion and further improves the mechanical properties of the weld.



Corner joint ballistic qualification panels were produced and were virtually distortion free after welding. The low distortion of the FSW is another productivity advantage of the process. FSW procedures are currently being developed to eliminate the need for a seal weld by forming an integral fillet along the root of the corner joint.



Based on successful demonstration on the corner joint panels, GDLS identified the sponson subassembly as a structure that could take advantage of the low distortion joints produced by the FSW process. The sponson structure consists of corner and T-joints that are presently GMAW. The welded assembly distorts considerably during fabrication requiring the use of thicker plate materials and extensive post-weld machining. <BR.

The goal of this task is to reduce fabrication costs by controlling or eliminating distortion through the use of both distortion modeling and more efficient fabrication methods. Initial validation results showed that the FSW mock-up panels were virtually distortion free while the GMAW panels had considerable angular distortion. The tooling methods that were developed to produce the FSW mock-ups will be incorporated by GDLS into the planning and design of future production tooling.

Industry and Navy Acceptance



The NJC worked directly with General Dynamics Land Systems Division and the AAV Team to ensure that the FSW procedures developed meet design requirements and are compatible with production conditions. The technology developed under this project was transferred to GDLS through technical briefings, FSW machine specifications, tooling concepts and hands-on operator training on the FSW process.

Implementation

GDLS has converted a large machine tool into a FSW machine in the Lima Army Tank Plant in Lima, OH. This machine is being used to train GDLS welding operators and for further process development. The NJC is also assisting GDLS in the development of specifications for an additional FSW system for AAV production.

Commercialization and Technology Transfer

In addition to the implementation plans described above, the NJC Teaching Factory will support further transfer of this technology and the dissemination of the procedures and information to the Navy and industry. Friction stir welding equipment is commercially available from a number of companies.

Expected Cost Reduction

The 5 Year ROI is 25.8 to 1 with an expected savings of \$25.8M.

TIMELINE/MILESTONES

Start Date: July 1999
End Date: March 2002

Project activities include the following tasks:

- Develop friction stir welding procedures for butt and corner joints in 2519 aluminum.
- Prevent and control distortion during fabrication of the AAAV.
- Develop GMAW procedures to improve productivity and ballistic performance of welds in 2519 material.

FUNDING

Navy ManTech Budget: \$1,000K

Expenditures to Date: \$862K

PARTICIPANTS

Development Partners

Edison Welding Institute
General Dynamics Land Systems Division

Deployment Partners

General Dynamics Land Systems Division

POINTS OF CONTACT

Navy ManTech

Office of Naval Research
Mr. Steve Linder (Code 361)
(703) 696-8482
linderst@onr.navy.mil

Performing Activity

Navy Joining Center (NJC)
Mr. Tim Trapp
(614) 688-5231
tim_trapp@ewi.org